SUPPLEMENTARY REPORT

MODIFICATION OF D. C. MOTOR WITH MAGNETICALLY SUSPENDED ROTOR TO GIVE HIGHER MOMENTUM STORAGE CAPACITY

1 April 1970 to 31 July 1970

CONTRACT NO. NAS 5-11585

Prepared By:

Cambridge Thermionic Corporation
445 Concord Avenue
Cambridge, Massachusetts 02138

For:

Goddard Space Flight Center
Greenbelt, Maryland

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ON

THE MODIFICATION OF AN EXISTING D. C. MOTOR

WITH MAGNETICALLY SUSPENDED ROTOR

TO GIVE HIGHER MOMENTUM STORAGE CAPACITY

1 April 1970 to 31 July 1970

CONTRACT NO. NAS 5-11585

GODDARD SPACE FLIGHT CENTER

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II SUMMARY

This report describes the modification of the No. 1 D.C. Motor with magnetically suspended rotor. The purpose of this modification is to increase the performance characteristics so that they are compatible with existing momentum storage devices.

A 2.1 lb. flywheel was added to the existing rotor which necessitated improving the total magnetic support capability of the bearing. This was done by adding two more ridges to each rotor and stator pole face. The addition of the ridges increased the support capability of the bearing without increasing the power requirement.

A stronger permanent magnet was installed in the rate generator circuit so that a sufficient rate signal could be generated with the increased rotor weight.

The existing motor and bearing housing was discarded in favor of a rigid clamping frame to accommodate the six inch diameter flywheel. This arrangement was agreed upon before-

hand by the Technical Officer of the Contracting Agency. A portion of the old housing was used to support the motor armature and commutator.

These modifications successfully improved the support capability, stiffness and efficiency with no increase in power consumption. The significant data from this is shown in the Performance of Work section of this report.

The operationalMagnetic Bearing and Motor with Flywheel was delivered to Goddard Space Flight Center on 29 July 1970.

III STATEMENT OF WORK

A. Scope.

Modification of No. 1 2-Phase Motor with magnetically suspended rotor to increase momentum storage capacity.

B. Technical Requirements.

The following are the technical requirements of the modification. All other technical requirements remain the same.

1. Maximum diameter of motor - 6 inches.
2. Inertia about axis of rotation - .003 slug $ft.^2$ minimum.
3. Additional weight allowance - 2.25 lbs.

C. Schedule.

The work was to be started upon receipt of motor & bearing No. 1 and completed on or before 31 July 1970.

D. Documentation.

Documentation was to consist of a Supplementary Report following the completion of the modification.

IV PERFORMANCE OF WORK

A. Deviation from Original Modification Specifications.

1. Size

Although the flywheel did not exceed the maximum diameter of six inches, the necessary clamping frame increases the maximum diameter of the operational motor to 9.375 inches. This relatively large clamping frame was chosen because of the increase in force in the magnetic suspension system. The clamping frame also provided better visual observation of the magnetic bearing and motor and greatly improved the adjustment and measurement capability.

2. Moment of Inertia

The moment of inertia of the motor with the flywheel, through calculation, was found to be .00336 slug $ft.^2$, exceeding the minimum specification by .00036 slug ft^2. Later, during tests, it was necessary to install locking pins between the motor and rotor body. This necessitated cutting two slots in the rim of the flywheel for the machining operation on the motor and rotor body. Through calculations it was found that removing this material from the flywheel would reduce the moment of inertia to .00332 slug $ft.^2$ However, this value is within the limits specified.

3. Weight

To achieve the specified moment of inertia the total rotor weight was increased from 5.6 lbs. to 7.7 lbs. Therefore, the weight of the flywheel was 2.1 lbs. These figures were arrived at through testing and calculations on motor No. 1 before modification.

B. Changes in Magnetic Suspension System.

1. Rotor and Stator Pole Piece Design

The basic overall dimensions of the rotor and stator pole pieces were retained. However, two additional annular ridges were added to each rotor and stator pole face. The addition of these ridges improved the radial support capability by approximately 70% with no increase in power consumption. The axial force was increased by approximately 50% with the addition of the ridges, also with no increase in power consumption.

2. Housing Design

Because of the diameter of the flywheel (6 inches) the cylindrical housing could not be used. A "U" shaped clamping frame was selected as the best means of securing the magnetic bearing and motor. Because of the need for rigidity, the aluminum clamping frame with associated parts had a total weight of 25 lbs. The rotor, flywheel, and stator pole pieces brought the total weight to 36.8 lbs.

The "U" shaped clamp-frame was split in half so that the two ends of the magnetic bearing could be separated. Then, the rotor could be removed and replaced, and the bearing clamped back together without having to make any critical gap adjustments. This precision was obtained by using a lead-screw and two 1-inch diameter steel rods, fixed in one end and sliding in the other end.

A portion of the cylindrical housing was used to support the motor armature and commutator. This was also mounted on its own lead-screw and steel rods so that it could be adjusted for any position of the motor gap.

C. Motor and Bearing Tests.

1. Balancing

The Rotor was balanced so that it would perform properly while going through worst-case resonance speeds. The worst-case resonance points were 3,100 RPM (in-phase, unbalance) and 4,000 RPM (out of phase, unbalance). During an early balancing operation the rotor dropped out at approximately 3,000 RPM and came to a complete stop in 1 to 2 seconds. Inspection of the rotor showed that the motor pole pieces had turned approximately 10° and the motor would not operate properly. The motor was repaired and all parts of the rotor were pinned to prevent any more slippage. Balancing was continued until the motor could be run through the two worst-case resonance points with no more than ±.001 inch displacement from the axis of rotation.

2. Radial displacement versus force

   The radial displacement versus force test was performed to provide empirical data on the added pole face ridges in the magnetic suspension system. Tests were made at four different current levels in the suspension coils. The results are shown on page 14.

3. Axial displacement versus force

   The axial-displacement-versus-force test was performed in conjunction with the radial displacement test to complete the necessary data. It was found that the magnetic bearing was so powerful in the axial direction that it had to be mounted on a five inch steel "I" beam along with the device applying the force. This was required to prevent any large amounts of bending or expansion as was encountered on the work bench alone. The amount of axial force acting on each end of the rotor during operation was found to exceed 250 lbs. The results from these tests are shown on page 15.

D. Reliability.

No components were changed, therefore the component reliability remains the same.

The operational reliability is enhanced by the increased support capability of the suspension system and the rotor stabilizing effect of the flywheel.

E. Documentation.

Three technical progress letters were submitted on the modification during the period 1 April 1970 to 29 July 1970.

NEW TECHNOLOGY

No new technology was encountered during this portion of the project.

VI CONCLUSION

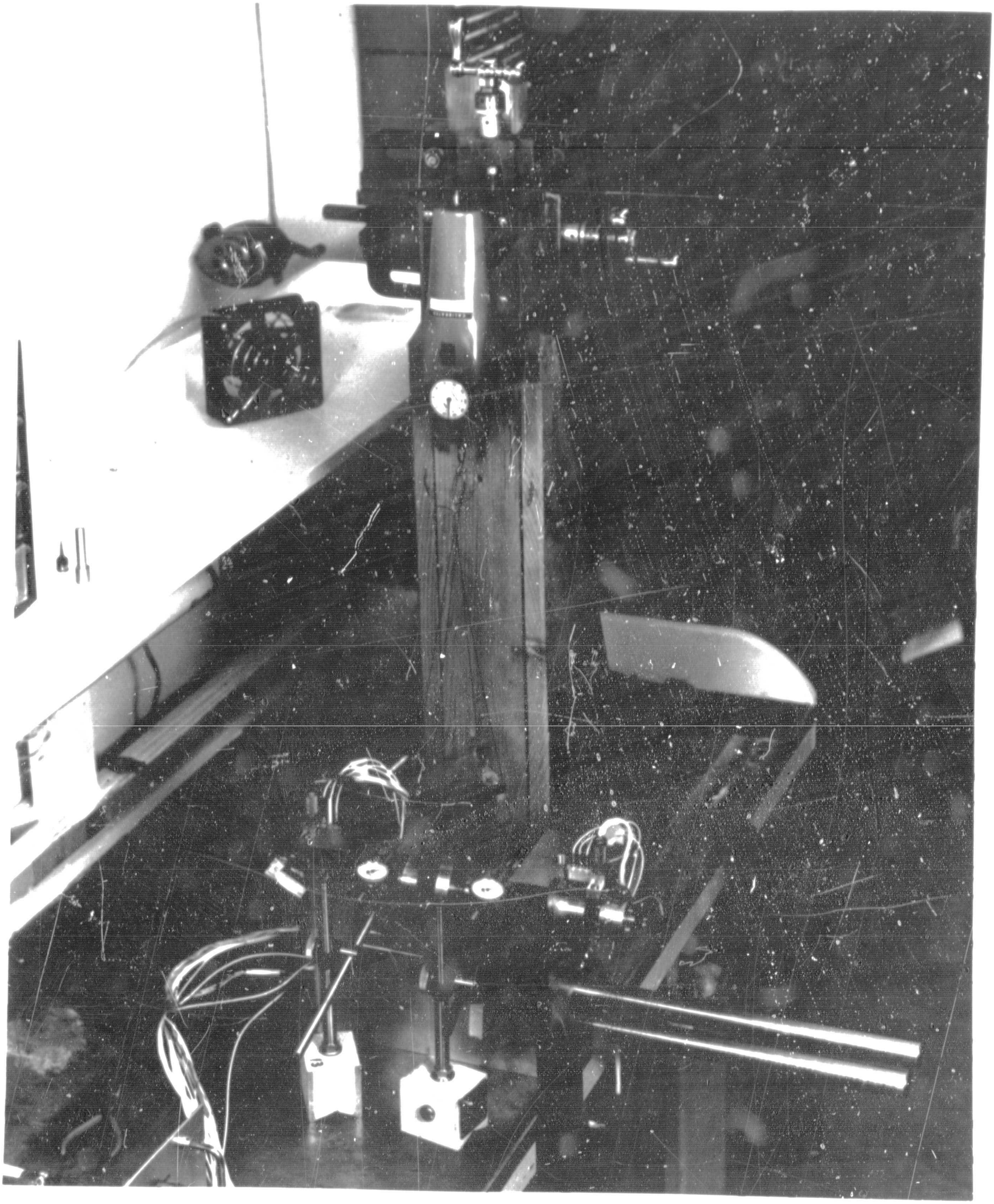
In conclusion we can say that the modification of Magnetic Bearing No. 1 was extremely worthwhile.

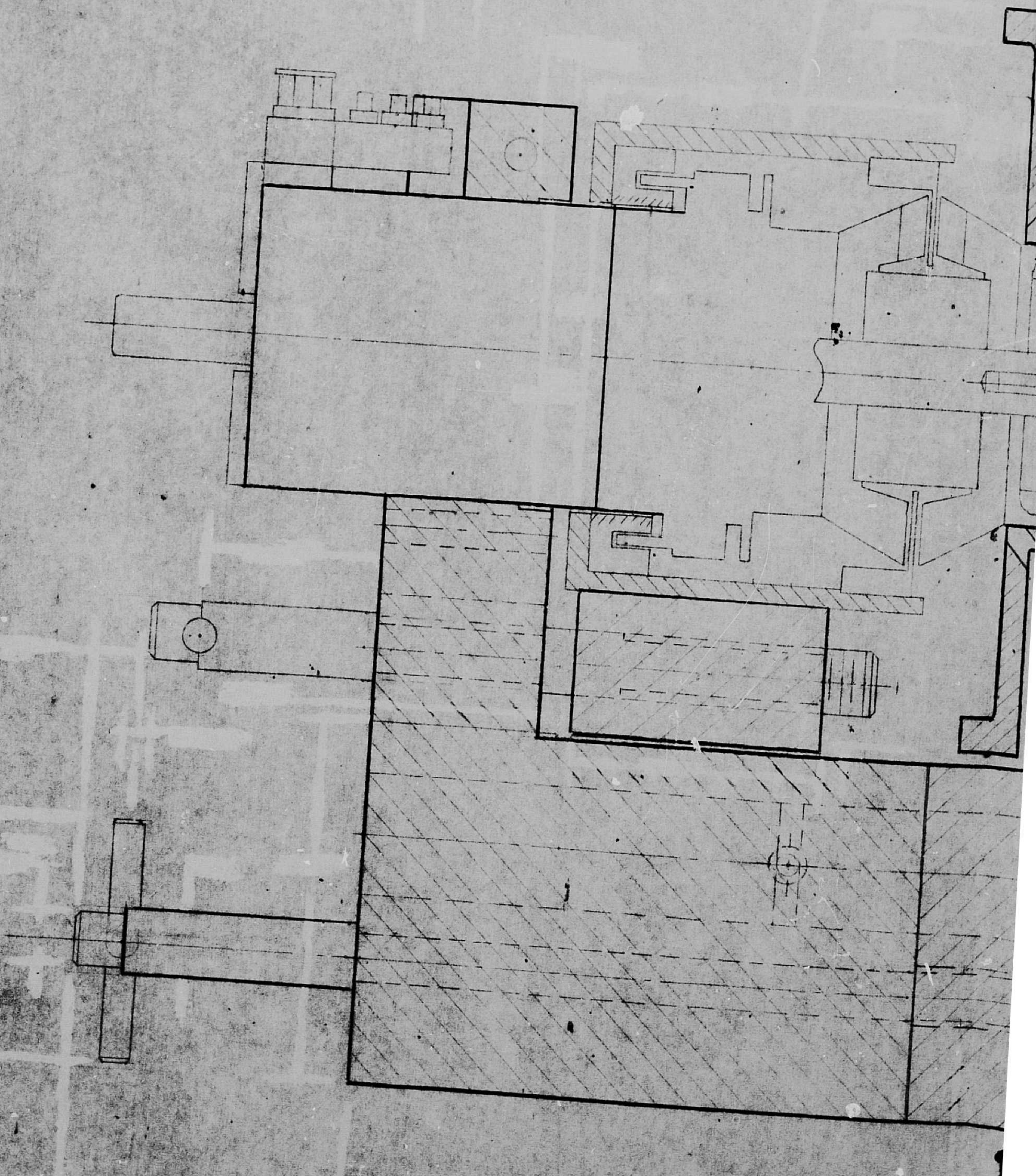
First of all, the addition of the rings on the rotor and stator pole faces proved that the suspension system's efficiency could be increased substantially without an increase in power consumption.

Secondly, the clamp-frame construction improved the accessibility and assembly of the bearing and motor for testing purposes without degrading performance.

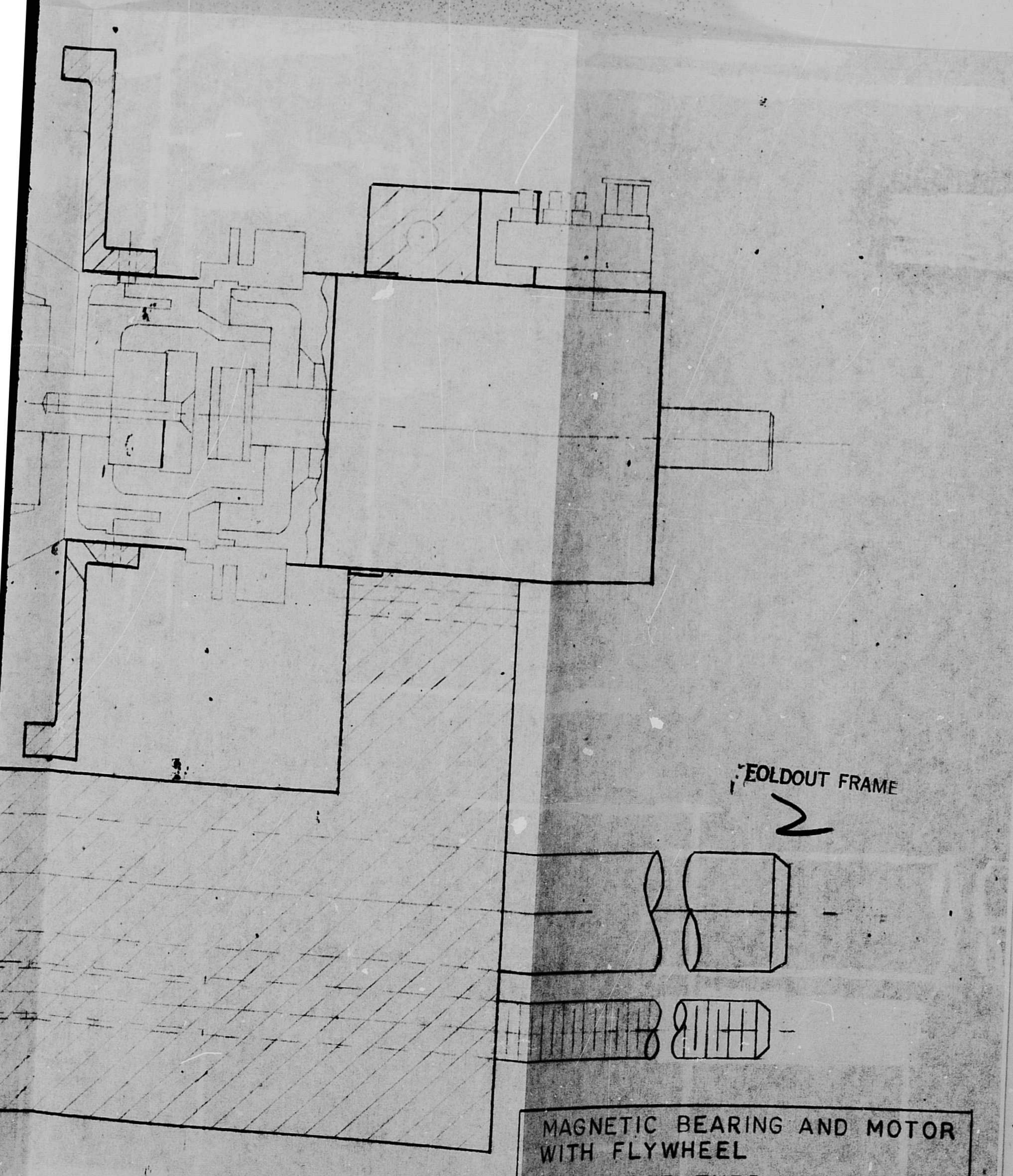
The addition of the flywheel to the No. 1 Magnetic Bearing will broaden the scope of data and give more valuable information about magnetically suspended rotors.

VII APPENDIX I - ILLUSTRATIONS

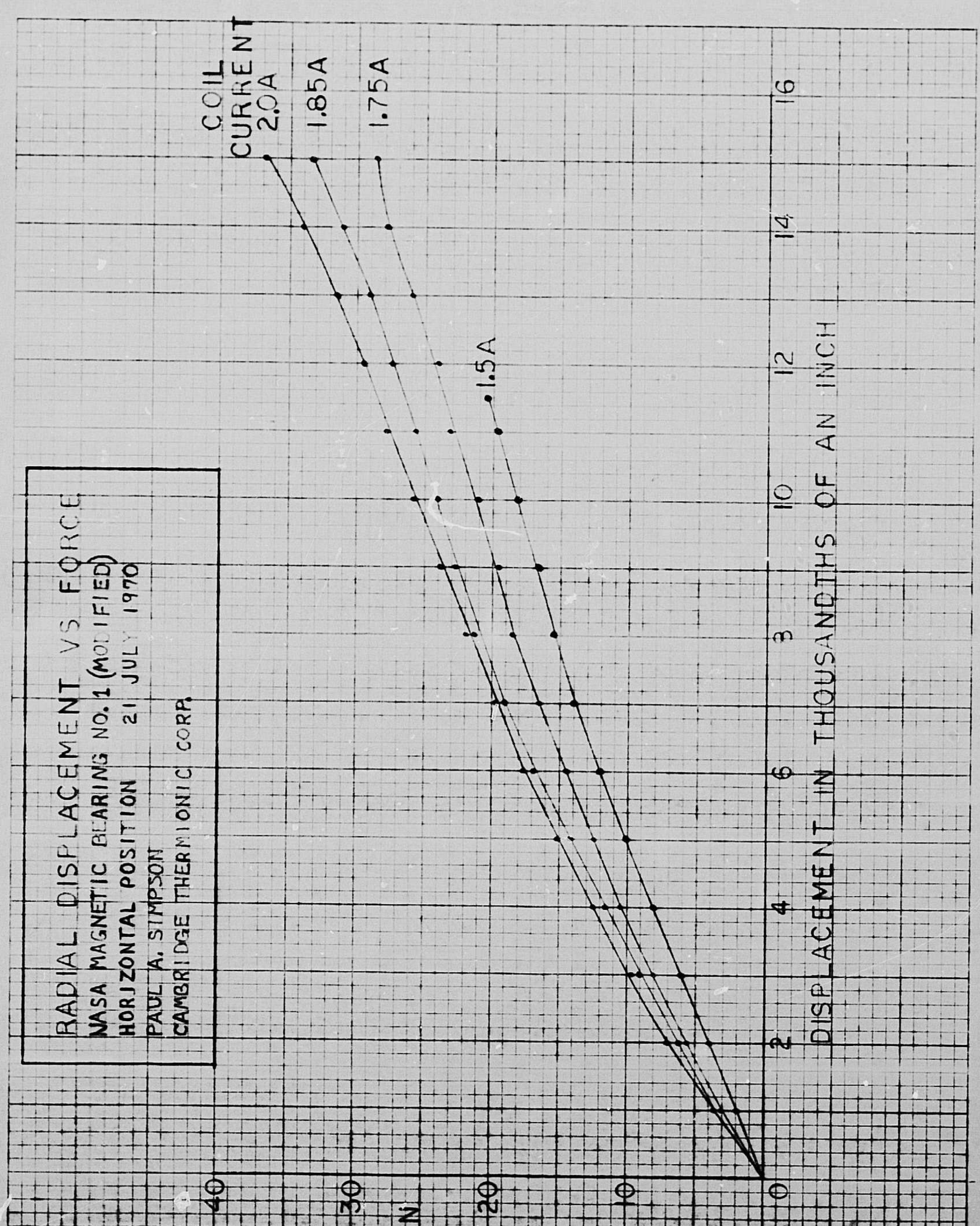




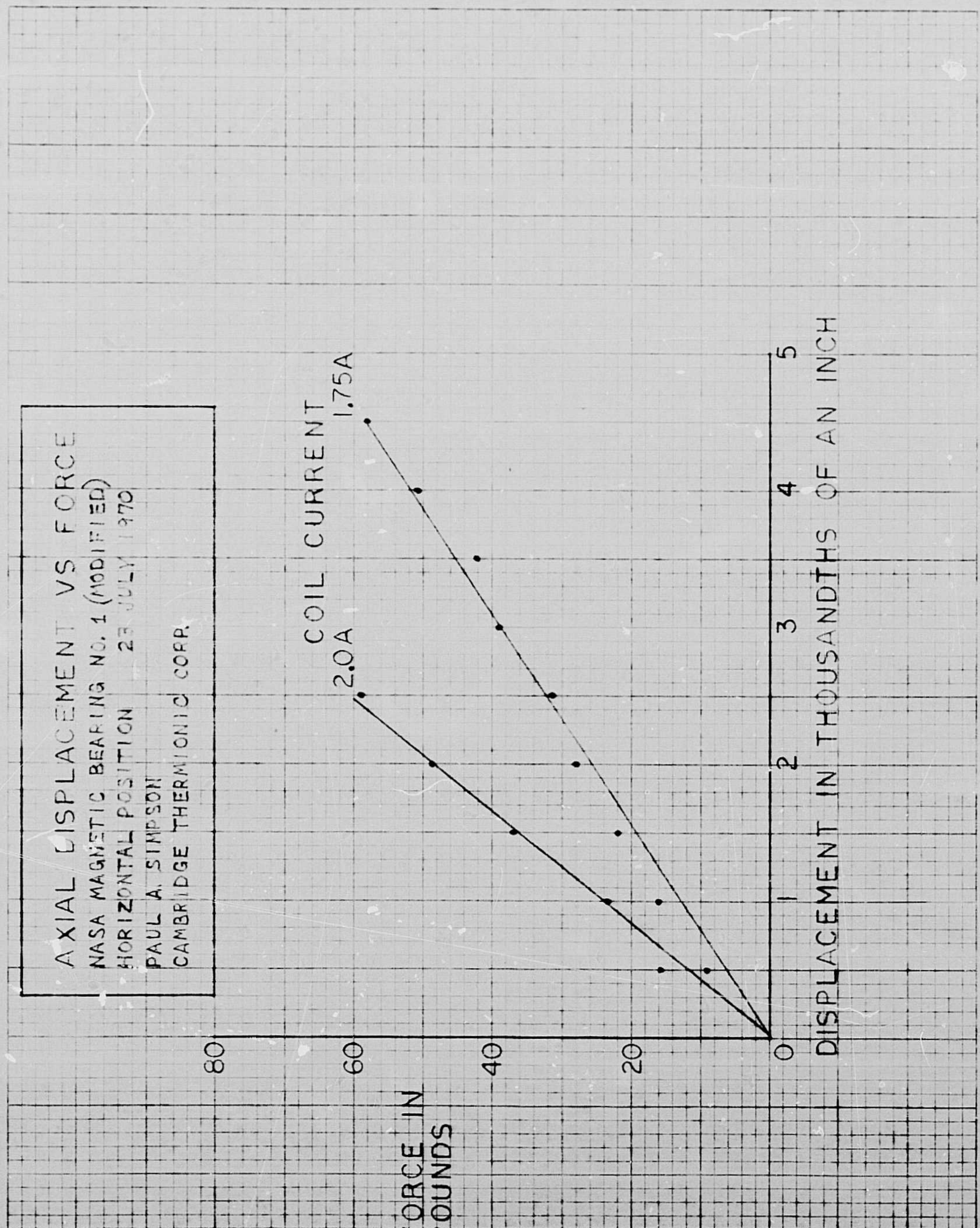
FOLDOUT FRAME



MAGNETIC BEARING AND MOTOR WITH FLYWHEEL
CAMBRIDGE THERMIONIC CORP.
12 OCT 1970



10 Squares to the Inch


AXIAL DISPLACEMENT VS FORCE
NASA MAGNETIC BEARING NO. 1 (MODIFIED)
HORIZONTAL POSITION 23 JULY 1970
PAUL A. SIMPSON
CAMBRIDGE THERMIONIC CORP.
COIL CURRENT
2.0A
1.75A
FORCE IN POUNDS
0
20
40
60
80
DISPLACEMENT IN THOUSANDTHS OF AN INCH
1
2
3
4
5